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Trends and Perspectives in Augmented Reality

Brian Goldiez[1], Fotis Liarokapis[2]

Institute for Simulation and Training, University of Central Florida[1]
Faculty of Engineering and Computing, Coventry University[2]

Summary

Training in the real environment is not easy, mainly due to socio-technological barriers. This chapter explores the potential effectiveness of augmented reality (AR) applied to training. We discuss previous applications of AR in live-training and findings arising from formative evaluations of these systems. Various approaches for applying AR to training are discussed. Overviews of the most characteristic evaluation methods as well as suggestions on assessing the performance of AR in training are provided.

1 Introduction

AR describes a technology where the real world is the baseline, and additional information from a computer-generated sensory display is added. AR is contrasted with virtual reality (VR) where the baseline is a synthetic (artificial) environment and the desired state is complete immersion of the human sensory system within a computer-created environment. As one adds more computer augmentation to a real world, the demarcation between virtual and augmented becomes blurred. Rapid advances in technology have contributed to blurring. Milgram (2006) has characterized a variety of continuums between the real and virtual worlds that reflect different ways one can view the interaction and use of the technology. The confluence of views of realities provides opportunities for adapting technologies from one domain to another and the opportunity to adapt human performance studies across domains.

There are three major characteristics of AR systems described by Azuma (1997). First, AR systems must seamlessly combine the real world with virtual information. This combination is typically considered in the visual domain, but is not exclusively restricted to it. Second, an AR system must operate in real time. That is, an AR system must provide responses commensurate with the system using the AR, in this case a human. Third, an AR system must spatially register the display with the real world in three-dimensional (3D) space. Currently there are two broad application areas for AR: decision-making tasks, where mobility is not critical; and tasks where mobility is of primary importance (e.g., navigation).

1.1 Technical Requirements for AR Systems

Research in tracking, display, and interaction technologies contribute to the immersiveness of AR systems, and new mathematical algorithms improve the effectiveness of the software system and realism of the visualization output. To correctly register the computer-generated objects and real world, accurate tracking of the coordinates of the participant's point of view is required. When training requires a stationary user position, the registration process is much easier than if the user is moving (Azuma, 1997). In both systems, accurate alignments between the virtual and real objects are required to avoid the appearance of floating objects. The common tracking techniques are vision or sensor based. Sensor based systems typically use magnetic or sonic devices to detect the user's position while vision based systems use cameras and visually distinctive markers to locate the user's position in an environment. These markers called fiducials are used in indoor systems with good results (Kato, Billinghurst, Poupyrev, Imamoto and Tachibana, 2000). Other indoor systems employ hybrid-tracking technologies like magnetic and video sensors to achieve good registration results. In outdoor and mobile systems, other sensor devices are used, such as the Global Positioning System coupled with orientation sensors (e.g., digital compasses).

AR systems typically use special displays to immerse participants in augmented environments. Head mounted displays for AR include optical or video see-through, which project merged computer generated and real images onto the user's eyes. However, there are other ways to immerse the user, such as large area displays, or stereoscopic glasses. Regarding interaction technologies, many commercially available hardware devices can be used to increase the level of interaction between participants and computing devices. Thus, a robust AR system must integrate an ergonomic software and hardware framework, and address the following: (1)

calibration and accurate user-viewing position; (2) *natural interaction*; and (3) *realistic rendering of virtual information.*

2 Review of State of the Art in AR

The literature is organized by successively considering AR applications, prototypes, components and concepts. AR applications exist (principally in laboratories or as prototypes) and have been subjected to some type of evaluation by humans. Prototypes are essentially AR systems that have been created, but generally have not been evaluated by users. Components are subsystems of AR systems. Concepts are ideas or concerns that have not been reduced to practice.

A further categorization of AR literature supports work by Goldiez (2004) that pointed to technological hurdles in AR in the areas of tracking and visualization. Tracking can currently be accomplished at a precise level in small spaces and in gross terms in larger areas. Visualization that makes added content indistinguishable from the real world requires graphics processing and display technology that does not currently exist in a mobile computing environment and minimally exists in a fixed setting. Many technical problems are mitigated when mobility is restricted but with large impacts on cost and/or flexibility in AR usage. As AR systems are deployed for experimentation and demonstration, new issues arise, principally in human factors and ergonomics, because the focus of AR expands from technical only to encompass usage. A more complete review of the literature can be found in Goldiez, Sottilare, Yen, and Whitmire (2006).

It is worth mentioning that there is no perfect AR technology and all existing ones have some advantages as well as limitations. To overcome the limitations of each technology hybrid AR systems can be employed to meet requirements that do not fall strictly into one category noted above. These hybrid AR systems combine different vision techniques and hardware devices to achieve results that better meet a user's requirements. Obviously, hybrid systems can further immerse participants but they will also generally increase the overall cost of the AR system because they might stretch the limits of the technology and have special integration and operational needs.

2.1 AR Application Domains

AR systems have been developed to facilitate improved human performance in areas such as entertainment, medicine, communications, navigation/decision- making, and military-oriented operations.

2.1.1 Entertainment

AR is being used in several areas in the entertainment industry. As examples, Liarokapis (2006b) describes how to transform a traditional arcade game into 3D and then into an AR interactive game. Initial studies found that users preferred the AR experience in terms of enjoyment. Cavazza, Martin, Charles, Marichal and Mead (2003) created an interactive system that immerses the storyteller into the background environment while Gandy et al. (2005) integrates users into a scenario based on the *Wizard of Oz*. A simple tennis game has been developed using commercially available Bluetooth cellular technology (Henrysson, Billinghurst and Ollilia, 2005).

2.1.2 Medicine

The medical field currently benefits from AR systems. For example, a Virtual Retinal Display (VRD) is being used for patients who suffer from poor vision and as a surgical display (Viirre, Pryor, Nagata and Furness, 1998). Scheuering, Rezk-Salama, Barfufl, Schneider and Greiner (2002) report on using a video see through HMD to overlay imagery during surgical procedures. Also, Vogt, Khamene, Sauer, Keil and Niemann (2003) developed a system to visualize x-rays, CT scans, etc., onto a person or mannequin by utilizing a retro-reflective marker tracking system. .

2.1.3 Communication

Several AR systems have been developed to facilitate communication and collaboration. Regenbrecht, H., Ott, C., Wagner, M., Lum, T., Kohler, P., Wilke, W. Mueller, E. (2003) describe an AR conferencing system allowing users to meet without leaving their desks. Billinghurst, Belcher, Gupta, and Kiyokawa (2003) describe two experiments investigating face-to-face collaboration using a multi-user AR interface. These results, however, found no advantage in using AR due to limitations from restricted peripheral vision.

2.1.4 Navigation

AR has been used to facilitate navigation and wayfinding. As part of the LOCUS project, Liarokapis (2006c) developed a system that uses AR and VR techniques to enhance mobile navigation by guiding pedestrians between locations in urban environments. Two prototypes were developed for outdoor navigation, one based on manually placed fiducials and another based on natural feature selection. The first prototype has robust tracking, but limited range, while the opposite is true for the second prototype. A hybrid approach using natural features and GPS is being researched that should provide better tracking efficiency. Goldiez (2004) utilized the Battlefield Augmented Reality System (BARS) to study the benefits of using AR in search and rescue navigation by exploring using different map displays to facilitate navigation through a maze. Results determined that BARS does improve user performance in specific situations.

2.1.5 Spatial Relations using AR

Bennet and Stevens (2004) describe a projection augmented, multi-modal system to explore how interaction with spatially coincident devices affects perception of object size. Results showed that performance in combined (visual/haptic) conditions was more accurate in distance estimation, verifying the theory that a person's perception of size is magnified by using more than one sense. Grasset, Lamb and Billinghurst (2005) investigated how a pair of users, one user utilizing AR (exocentric view of maze) and one utilizing VR (egocentric view of maze) can accomplish a collaborative task. Results concluded mixed space AR collaboration does not disrupt task efficiency.

2.1.6 Military-Oriented AR Systems

BARS is an important military based AR application that was developed by the Naval Research Laboratories for use in urban settings. BARS has served as a de facto integration platform for a number of technological and human performance research efforts. For example, it has been used in several experiments investigating the impact of various technological innovations on human performance (e.g., Goldiez, 2004; Livingston, Brown, Julier and Schmidt, 2006). Livingston et al. developed innovative algorithms to facilitate pointing accuracy and the sharing of information among

BARS users. Additionally, Franklin (2006) discussed experiments using a system similar to BARS, but developed by QinetiQ to assess the maturity of AR to supplement live training. In the QinetiQ developed system a virtual aircraft was inserted into live ground assets, which could see and interact with live participants, but live participants had no knowledge of the virtual world. The results suggested a more robust interface to the live environment was necessary and the bulkiness of the AR equipment was an impediment to performance. To overcome limitations in the field-of-view, users suggested the use of small visual icons on the display periphery to cue the user to aircraft position. Discrepancies between the real and synthetic worlds with respect to environmental effects were problematic to training.

2.2 AR Components

At a top level, AR components include visual software and hardware, spatial tracking devices, other sensory devices, computing, and consideration of ergonomics. Integrating components creates an AR system.

2.2.1 Visual Components

Visual software and hardware are key factors distinguishing AR from VR. Superimposing virtual images onto a real background is challenging and relies on efficient processing to create realistic scenes, compensation for motion, and tracking tools for placing images in the correct position. Several factors contribute to the VR/AR distinction, including the need in AR to accommodate differences in dynamic changes in brightness and contrast between the real and virtual parts of the scene, latency in overlaying the virtual image onto the real world, image fidelity differences, helmet mounted display weight, etc.

A variety of visualization research has been conducted to enhance AR. A novel approach was taken by Fischer, Bartz and StraBer (2005), who reduced the visual realism of the real environment to better match the computer generated object(s) being superimposed onto the real world. An alternative approach for interacting with smaller 3D objects in AR is suggested by Lee and Park (2005) who use blue augmented foam as a marker. Mohring, Lessig and Bimber (2005) describe the technology of video see-through AR and its development on a consumer cell phone achieving 16 frames-per-second. Ehnes, Hirota, and Hirose (2005) have developed an alternative to the HMD based on a computer controlled video projection system that displays information in the correct place for a user.

2.2.2 Tracking Components

Tracking in AR is the operation of measuring the position of real 3D objects (or humans) that move in a defined space. Six degree of freedom (6DOF) tracking is referred to as the simultaneous measurement of position and orientation in some fixed coordinate system such as the earth. It is normally required that the location of the tracking device (e.g., camera) and item being tracked (e.g. a trainee) be simultaneously and continuously known in 6DOF. The most significant technologies available for tracking in AR environments can be subdivided into six broad categories: mechanical, electromagnetic, optical, acoustic, inertia and GPS. As with visual systems, tracking systems drive AR implementations into fixed or limited motion situations to allow for display rendering and for precisely tracking human appendages or important components. Wider range motion AR systems are less precise and therefore limit the degree the virtual image aligns with the real world.

Computer vision tracking is also a major area of research for AR. Vision-based tracking (Neumann and You, 1999) enables the potential recognition of an object in a natural environment that serves as a fiducial. Software algorithms have been developed by Behringer, Park, and Sundareswaran (2002) to use vision-tracking to recognize buildings and/or structures. Naimark and Foxlin (2005) describe the development of a hybrid vision-inertial self-tracker that utilizes Light Emitting Diodes (LEDs). Tenmoku, Kanbara, and Yokoya (2003) describe an alternative to vision-based tracking that integrates magnetic and GPS sensors for indoor and outdoor environments. The user’s location is tracked utilizing a combination of RFID tag(s) deployed in the environment, GPS (outdoors) and magnetic (indoors) sensors.

2.3 Human Factors/Mobility

Even a system with flawless tracking and visual augmentation would be worthless if the user were unable to perform the desired tasks comfortably and effectively; thus, ergonomics cannot be overlooked in AR development. Weight, location of controls, and mobility all influence user performance. Liarokapis (2006a) presents an overview of a multi-modal AR interface which can be decomposed into off-line, commercially produced components. A variety of interaction paradigms, such as the use of fiducial based icons, support physical manipulation of an object. Vogelmeier, Neujahr and Sandl (2006) from the European Aeronautic Defense and Space Company (EADS) discuss the need for similarity in various sensory interactions when wearing AR/VR equipment as compared to the real world. An attractive feature of AR is mobility and with it possible extensions in the variety and range of human interactions. Tappert et al. (2001) and Espenant (2006) discuss the possibilities of using AR based wearable devices as visual memory prosthetics or for training. Mobility in AR will also require considering user location. For example, Butz (2004) discuss approaches that consider using radio links and infrared or 3rd generation (3G) cellular technology to support mobility, enabling the acquisition of the user's location for subsequent processing of relevant data.

3 Advanced Concepts Impacting AR

The markets will determine when several technologies important to AR emerge, as it appears that several needed technical innovations are dependent upon developments in the commercial sector. These interrelated areas include advances in power management, computer packaging, and communications. Power management (power sources and power consuming devices) is important to sustained mobility and operations in AR. Computer packaging is another area where the commercial market will determine what products become available. The literature alludes to the need for devices that consume less power and are more compactly packaged.

Handheld and mobile computing may become an advantageous platform for hosting AR applications. Emerging mobile technology employs on-board computing and graphics rendering resources that are useful for AR applications. Researchers (e.g., Liarokapis, 2006c) are exploiting this technology, but are not creating the hardware or software operating systems. They are dependent upon the mobile industry to create products that are useful to AR while also serving the wider cellular marketplace. This type of leveraging is advantageous as development costs and economies of scale are borne by someone other than the AR community. However, the AR community must stand by the sidelines and wait for developments that may or may not occur.

A review of the literature suggests that when real and virtual environments are mixed, handling interruptions is a major unresolved issue. Unanticipated items (e.g., people) crossing the field of view could result in unacceptable anomalies in the AR visualization. The work of Drugge, Nilsson, Liljedahl, Synnes and Parnes (2004) showed that interruptions in AR occur due to unforeseen events (e.g., someone walking across a scene causing visual anomalies) but also are due to the tasks conducted by the user (e.g., divided attention tasks). This work could be significant to AR in providing a strategy for handling events that occur in the virtual world when mixed with the real world. Conceptually, one could envision an AR user marking an item of interest and having the AR system report back if the item's situation had changed, thereby possibly mitigating divided attention related issues.

Understanding context is another concept where a better understanding of the impact of mixing environments to create viable AR implementations is needed. Because AR uses the real world, which is naturally multi-modal, it is not yet clear what information needs to be captured prior to and during an AR experience to understand human activity that occurs during the AR experience. A wide range of environmental data and externally originated sensory stimuli could be relevant to creating an appropriate and dynamic AR experience.

In conclusion, AR systems-oriented research and development progress in the United States has been principally technological. Formal evaluations of this technology are not yet evident in the training related areas. Future work currently sponsored by the European Commission will create new VR and AR systems along with formal evaluations for various purposes.

4 AR Utility for Training

AR seems ideally suited to support training in navigation, manipulation of items, and decision-making. Experimentation has indicated benefits for using AR in training for certain applications. Early work demonstrated its usefulness in manipulation and spatial experiments (Goldiez, 2004). AR's role in supporting decision making requires a longer-term view with enhancements needed in technology before human performance benefits can be realized (Franklin, 2006). AR has shown benefits to enhance human performance in navigating and near-term benefits in training appear promising. In live (or live/virtual) exercises, AR could serve as an on-board instructor, guiding the trainee should he or she become lost or venture outside the desired training area. This capability could greatly simplify the tracking problems in AR by allowing the use of GPS or RFIDs for gross tracking and a more precise tracking mechanism at critical locations. Thus, for training, the aforementioned tracking problem can be controlled by appropriate scenario design coupled with the use of AR as a surrogate instructor.

AR offers the opportunity to improve various training subsystems. Visual simulation immediately comes to mind because of the potential for video or optical see through devices to add (or subtract) content from a scene. AR, though, can also augment the instructor by providing in situ tutoring (such as hints when the trainee is lost while learning to navigate) and individualized after action review of trainee activity in live and/or virtual exercises. Mobile AR also offers the potential for personalized training by providing information in a form most suitable for the user's needs.

At a conceptual level AR can also be envisioned as a technology that will facilitate better methods in team training. Because of its ability to provide additional information display as well as information storage and persistence, AR can facilitate mitigating team situational awareness issues by providing pointers and non-verbal communication into areas for team attention. It is logical to envision this sharing of information and enhanced situational awareness being used as a tool for training.

Dr. Walter Van deVelde, Program Officer for the European Commission's Future and Emerging Technology Initiative, noted in a brochure emailed to said author on August 11, 2006:

> "Current virtual and augmented reality environments try to provide the best display realism, taking for granted that this automatically leads to the best user-experience. Practice shows that this is not true: users do not easily feel fully engaged in high-tech VR worlds. On the other hand they can feel extremely present in simpler environments, like when chatting on line or when reading a book. A better understanding of this [presence] will give rise to new immersive interface technologies that exploit human perceptual, behavioral, cognitive and social specificities for stimulating a believable and

engaging user-experience of presence, in spite of using artificial stimuli…"(Van de Velde, 2006).

Investigations into measuring and controlling presence are potentially critical for training using AR because users will be interacting with real and virtual items and could need to distinguish between the two. Properly structured research in this area would thus yield valuable insights into strategies for handling interruptions. After-action review systems for live and virtual training have been prototyped; however, AR adds new complexities. An appropriate after-action review for AR should include the following: capturing relevant contextual information in the real world; identifying interruptions; and handling or correlating varying spatial positions and poses of the trainee with their real and virtual position.

Moreover, AR has the huge potential for improving training by integrating new and existing skills in training. In some cases, this might be done by providing AR training systems that have unique capabilities for testing & evaluating trainees. From another perspective more research into AR interface issues will likely help answer some key questions as well as help foster better training solutions and applications. Some additional aspects of the utility of AR for training could include enhanced assessment and diagnostic capabilities in the real-time portion of the system allowing trainees the ability to review actions and decisions from different perspectives. Potentially such AR systems could have the capability to visually compare the trainee's paths, actions, decisions, etc. to those of experienced experts such that trainees could see (and the instructor could discuss) differences between the novices and the expert's actions.

Several aspects of human-centered design should be studied with respect to making AR better suited to supporting training in various vocations. These include personalizing the software for training to certain classes of individuals and human factors considerations for hardware, noted above. The work of Liarokapis (2006c) using mobile technology adapted for VR and AR shows great promise for training, using virtual scenes at modest prices and good operating performance. Coupling location awareness (through techniques such as RFID's) with a digital compass provides reasonable information on user location. Rendering time and data transfer rates are currently insufficient for real time operation, but advances are being made by the cellular community. These types of devices represent a viable future delivery mechanism.

5 Conclusions

AR is an exciting technological development offering the opportunity to overcome many of the limitations in individualized virtual environment systems. These include performance limitations, such as self motion, and programmatic limitations, such as high costs and relatively large facility requirements. AR has its own set of issues, as noted in this chapter, which are being addressed by research teams across the globe. Most AR activity has been focused on computer graphics fused to the real world to create an immersive environment. While fully immersive systems are beneficial, there are more immediate and near-term opportunities for less immersive AR systems. A principal benefit in using AR is its apparent ease of deployment. Such deployable systems employing wearable computers provide increased flexibility for AR's use when and where needed. Moreover, coupling the broader view of AR with its classification into three categories and two usage areas encourages experimentation and development along more focused lines of research.

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